Using Regions of Interest for Adaptive Image Retrieval

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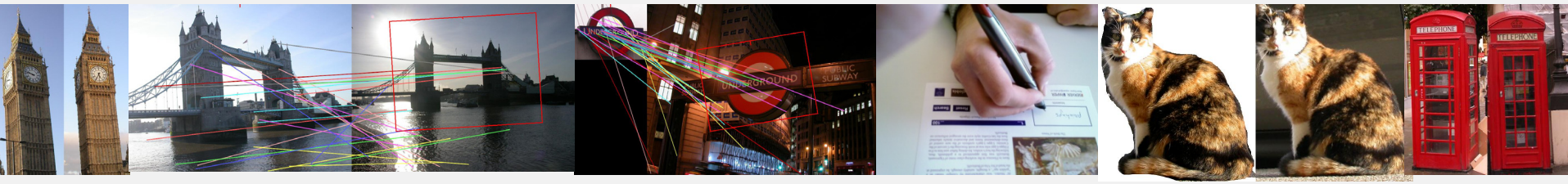

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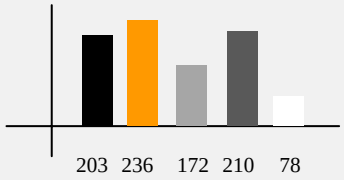
Content-Based Image Retrieval

Query by Example

Image Collection

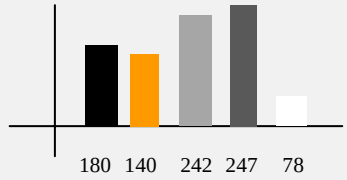
Query Image

Feature Vector



$$\sum_{i=0}^{d} (a_i - b_i)^2$$

Feature Vector



Simplified Comparison with Text IR

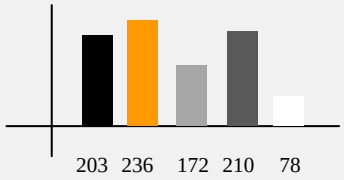
	CBIR	Text IR
What is the query?	Feature(s) of Image(s)	Set of keywords
What is desired result?	Ranked list of most-similar Images	(Ranked) list of Documents containing keywords
What contributes to distance/similarity?	Every difference between feature vectors (query + compared image)	Only keywords found in documents
How is query refined (e.g. using relevance feedback)	Adjust weights of features / images, add new features/images	Add new keywords, adjust weights

Adaptability in Query by Example

What contributes to distance?

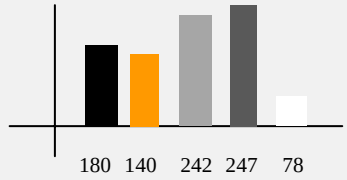
Query Image

Feature Vector



$$\sum_{i=0}^{d} (a_i - b_i)^2$$

Feature Vector

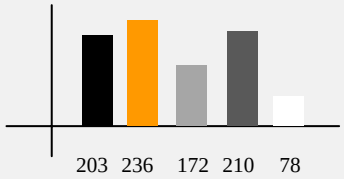


Adaptability in Query by Example

What contributes to distance?

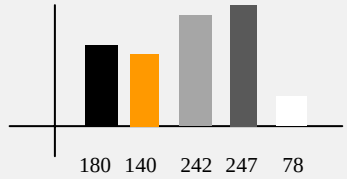
Query Image

Feature Vector



$$\sum_{i=0}^{d} (a_i - b_i)^2$$

Feature Vector



Overview of the Approach

Selecting Regions of Interest (ROI)

Matching Regions in Images

Similarity Between Corresponding Regions

Relevance Feedback

Conclusion & Outlook

Selecting Regions of Interest (ROI)

- Traditional Approaches: Rectangular Bounding Box

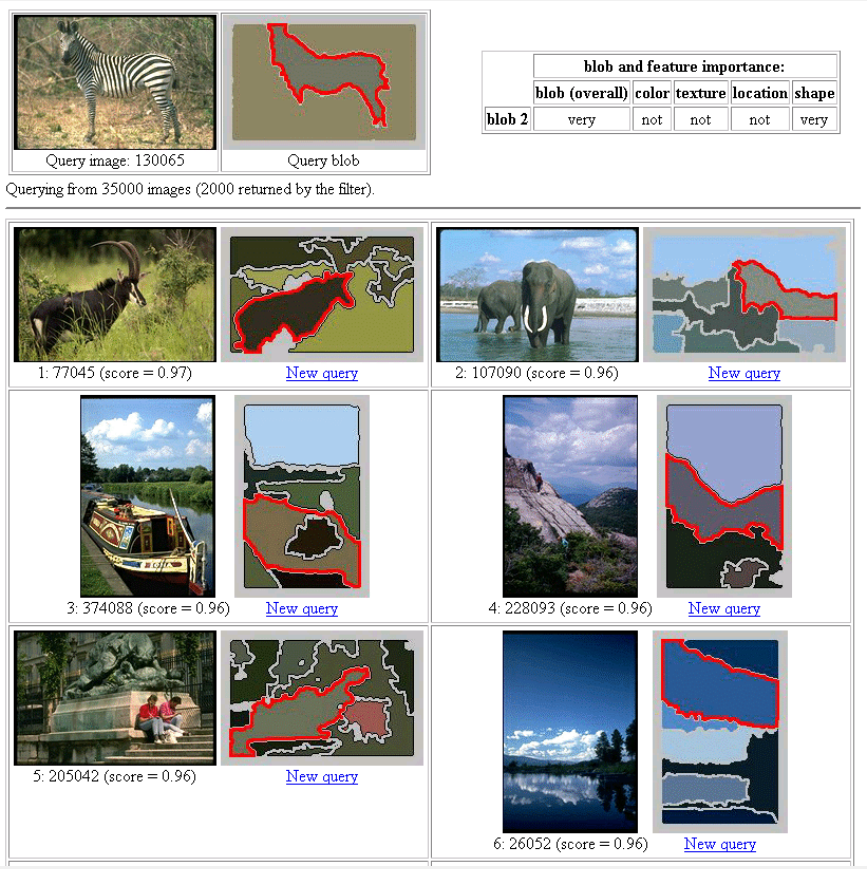
Use just the bbox as new query image

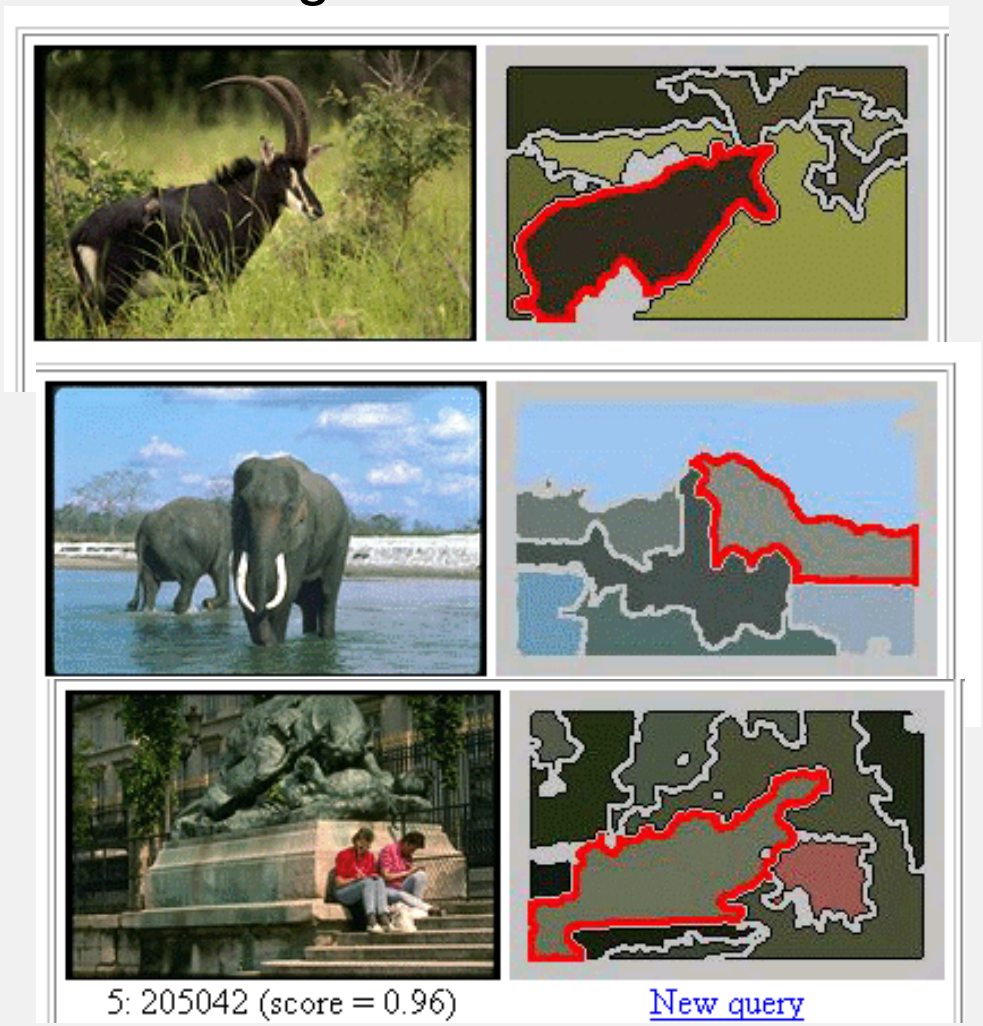
… but this matches entire images, not just interesting regions.

Selecting Regions of Interest (ROI)

- Traditional Approaches: Automatic Segmentation

Blobworld:





Selecting Regions of Interest (ROI)

- Intrinsic Bounds to Automatic Image Segmentation

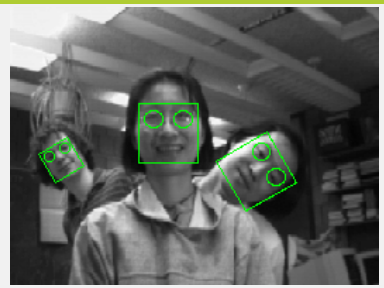
Selecting Regions of Interest (ROI)

Using Interactive Paper or Tablet PC

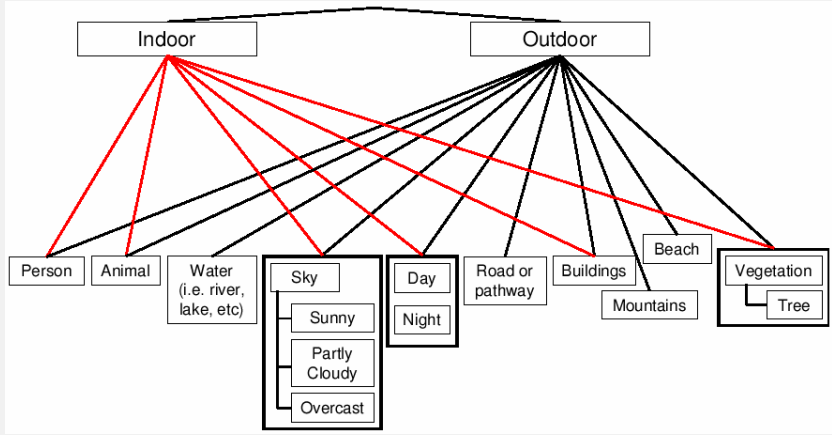
Used for query definition *and* relevance feedback

Identify High-Level Concepts

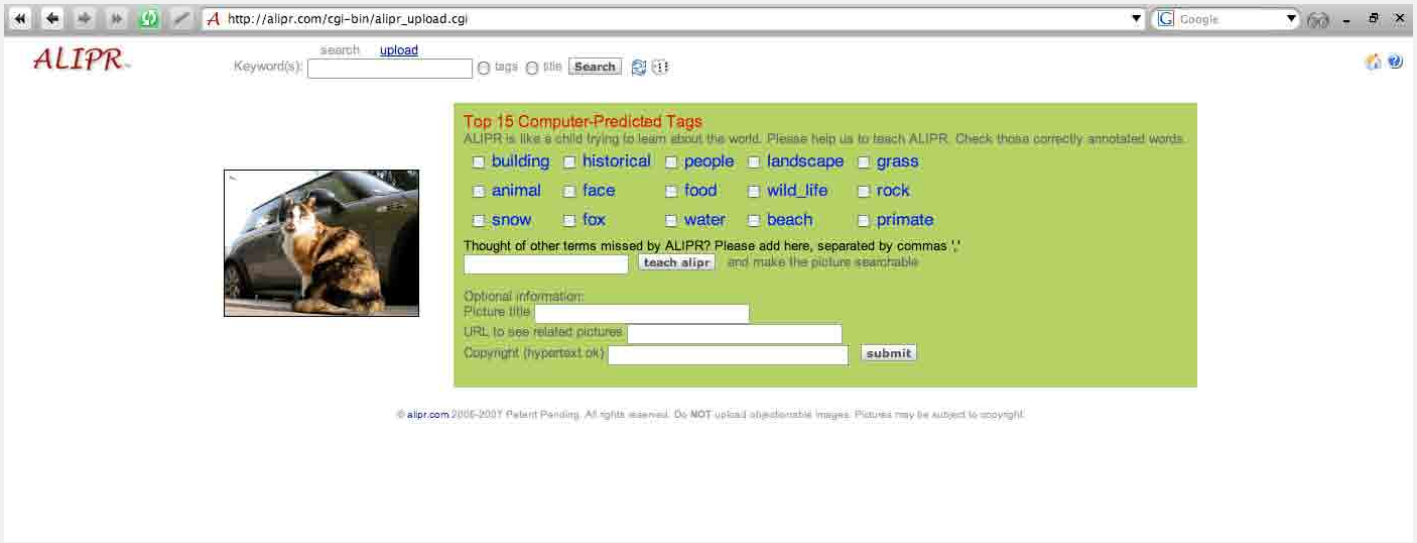
- Face Detection



- ImageCLEF
  - Visual Concept Detection Task
  - Automatic Medical Annotation



- ALIPR



Selecting Regions of Interest - Summary

- User selects Region of Interest (ROI)
- Input devices more appropriate than mouse & keyboard
- System tries to find high-level concepts within ROI

But how to match selected region?

Overview of the Approach

Selecting Regions of Interest (ROI)

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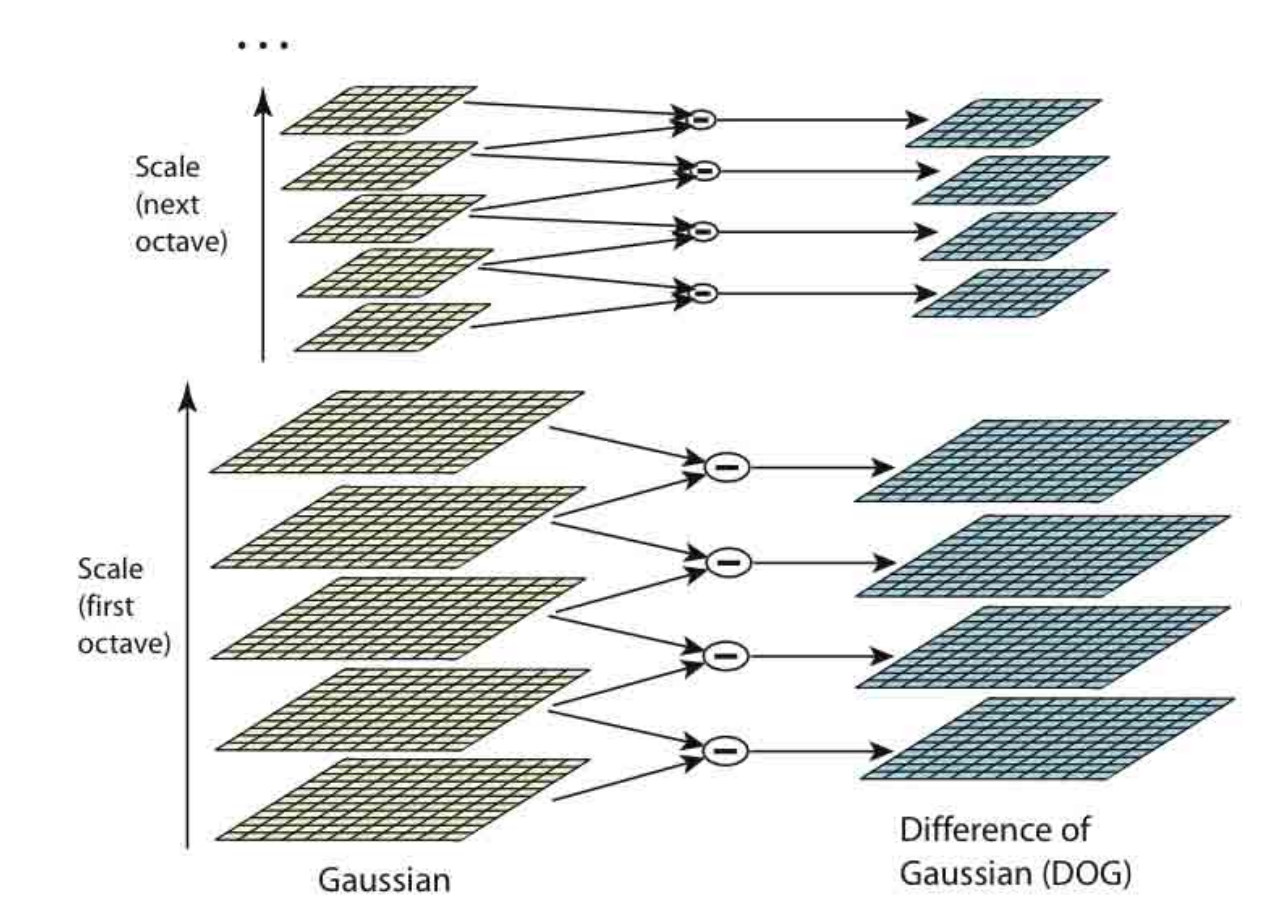
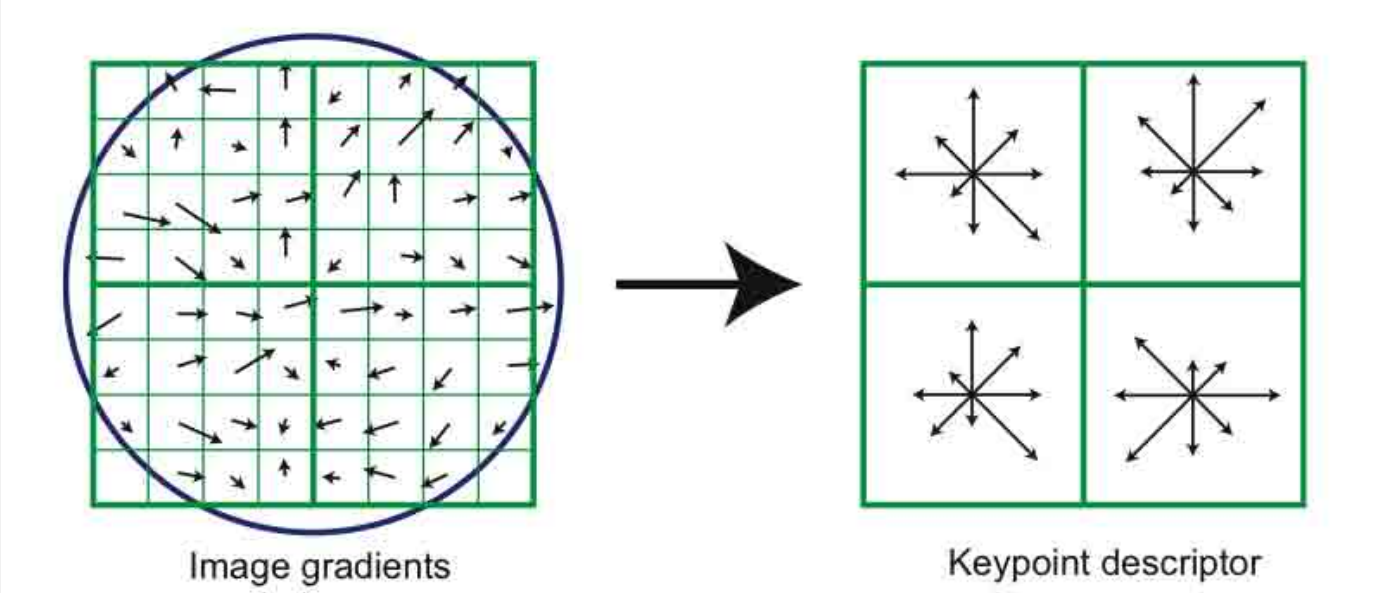
Matching Regions in Images: Keypoints

Generic Solution: SIFT (Scale-Invariant Feature Transform)



Matching Regions in Images: Keypoints

Generic Solution: SIFT (Scale-Invariant Feature Transform)



Matching Regions in Images: Keypoints

Generic Solution: SIFT (Scale-Invariant Feature Transform)

Keypoint Matching

1481 Keypoints

2536 Keypoints

Many!

For each keypoint in query

128 dim dist. - Slow!

find the two most similar keypoint in reference

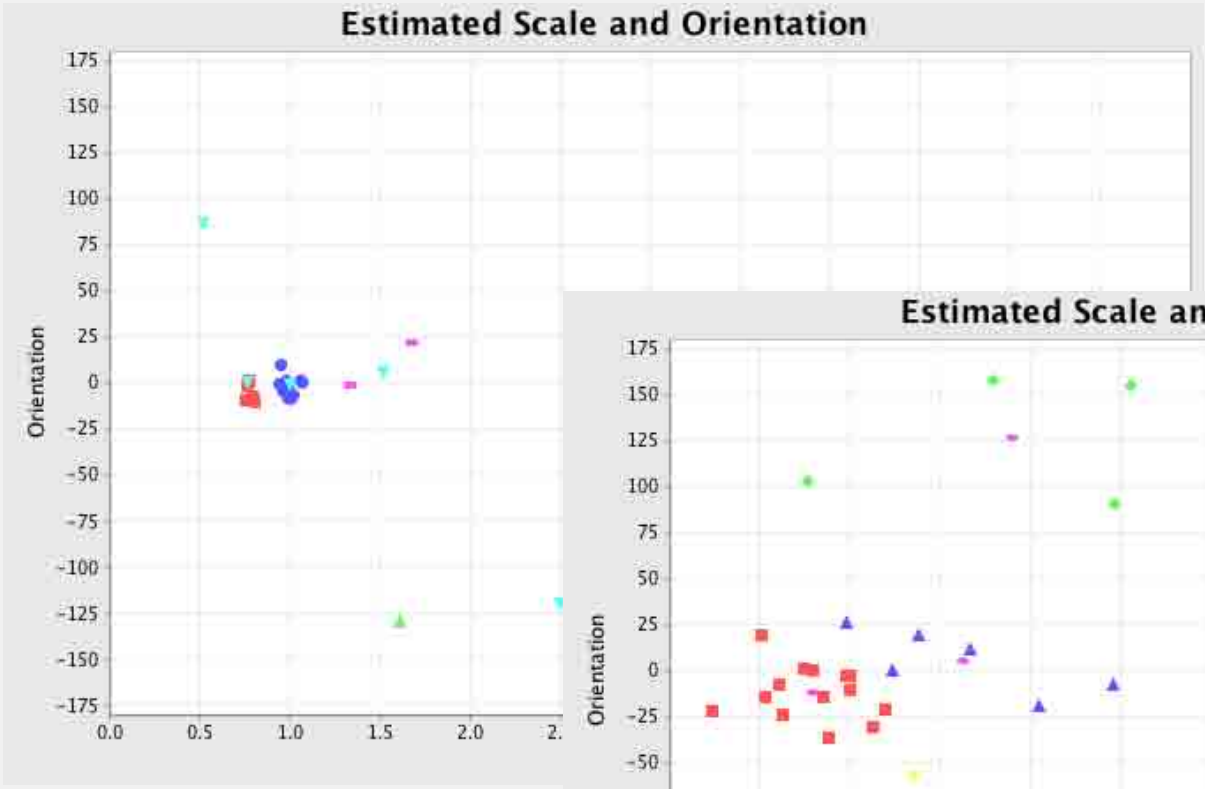
determine ratio: best_distance / second_distance

if better than threshold, keep as match

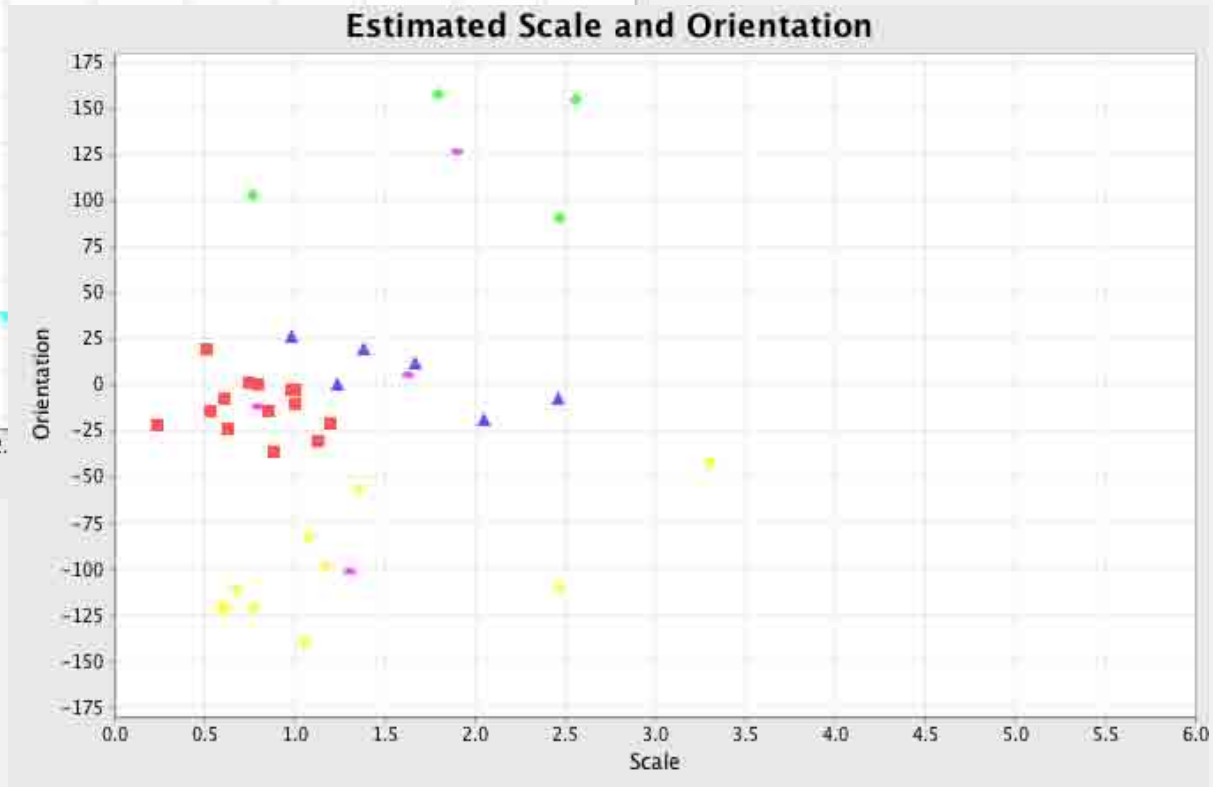
Hard to define!

End

Clustering and Filtering

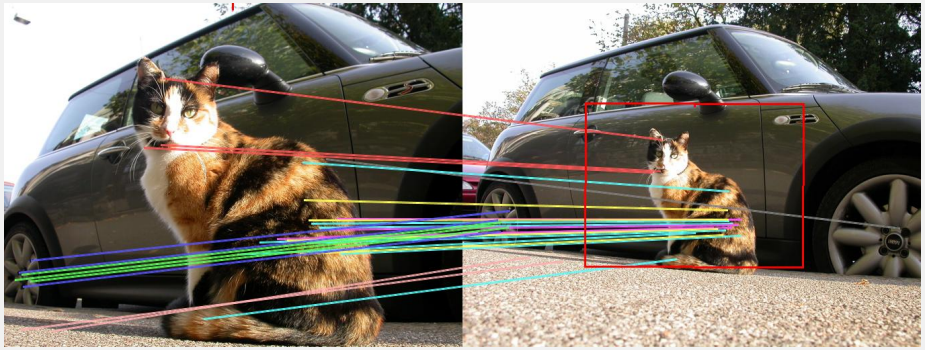


Input:
List of 50 best SIFT matches (no threshold)

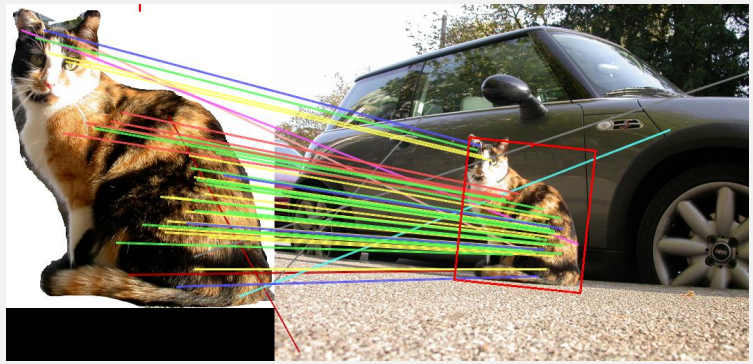


Filter Outliers with RANSAC

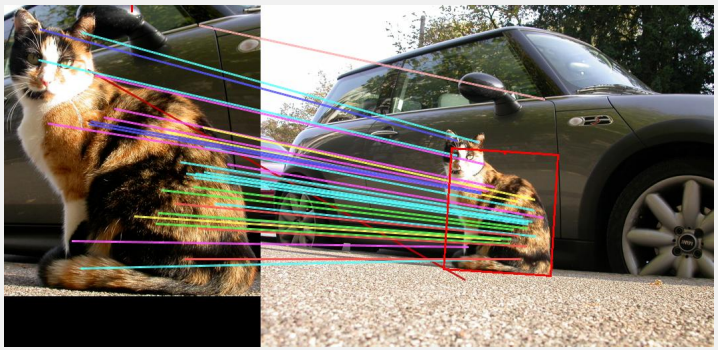
Keypoint Matching



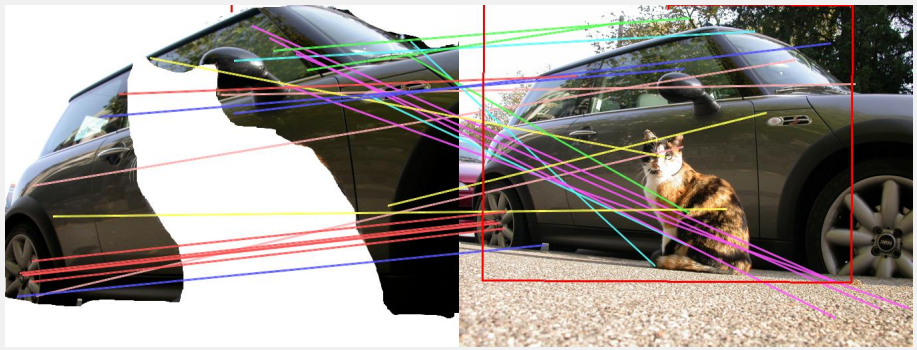
1481 Query keypoint: 924 ms
Early Termination: 629 ms



684 Query keypoint: 438 ms
Early Termination: 311 ms



900 Query keypoint: 576 ms
Early Termination: 401 ms



536 Query keypoint: 350 ms
Early Termination: 236 ms

Further Optimizations possible

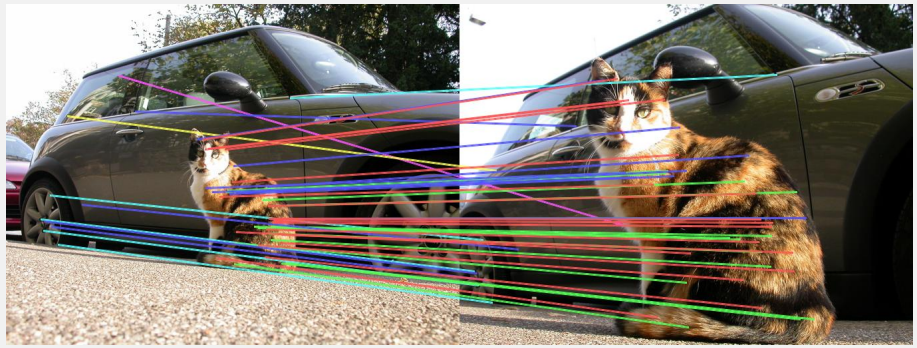
- Did not use any index so far
- Can be performed in parallel using multiple threads / computing cluster / Grid
- Add constraints:
  - Allow only certain rotations and scaling
  - Can be evaluted based on keypoint metadata
  - Example: Allow only 10° of rotation → 152 ms for cat region

- Remember:

  Number of images to perform matching on can be filtered based on high-level metadata (face, visual concept, tags,...)

Feedback

- Can be traced back to originating keypoint



- Can be used to refine transformation constraints
- Can be used to refine high-level concepts

Matching Regions - Summary

- Use invariant keypoint descriptors like SIFT originating from object recognition domain
- Allow more matches, but add clustering & filtering
- Use Early Termination and constraints to reduce time

But how to determine similarity?

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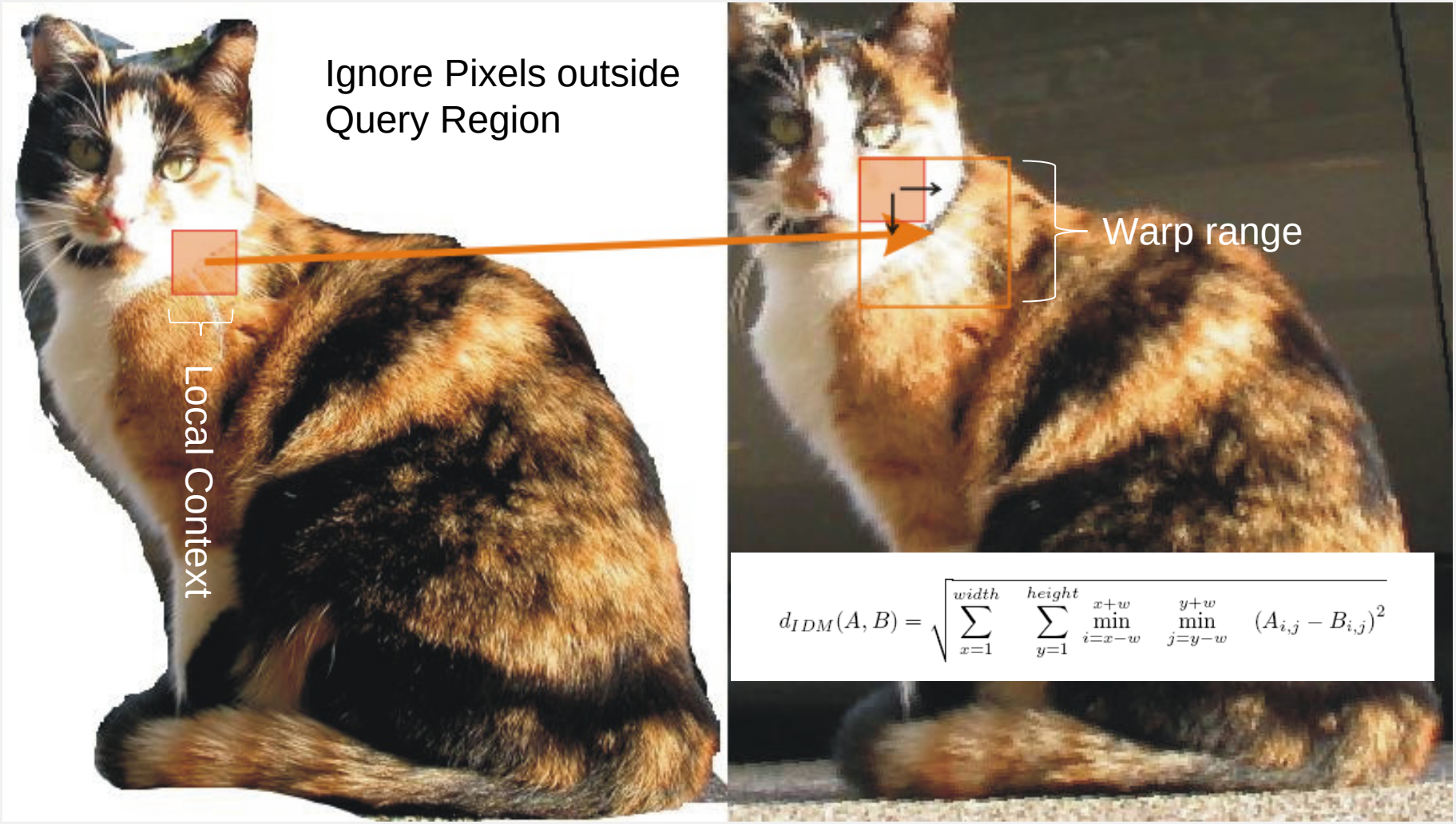
Determine and Apply Affine Transformation

Similarity Between Corresponding Regions

Image Distortion Model (IDM)



Conclusion

Selecting Regions of Interest (ROI)

using Interactive Paper or Tablet PCs to
- Give maximum flexibility to the user
- Better unterstand what is the need (concepts)

Matching Regions in Images

using keypoints within query regions
- use clustering and filtering
- determine transformation

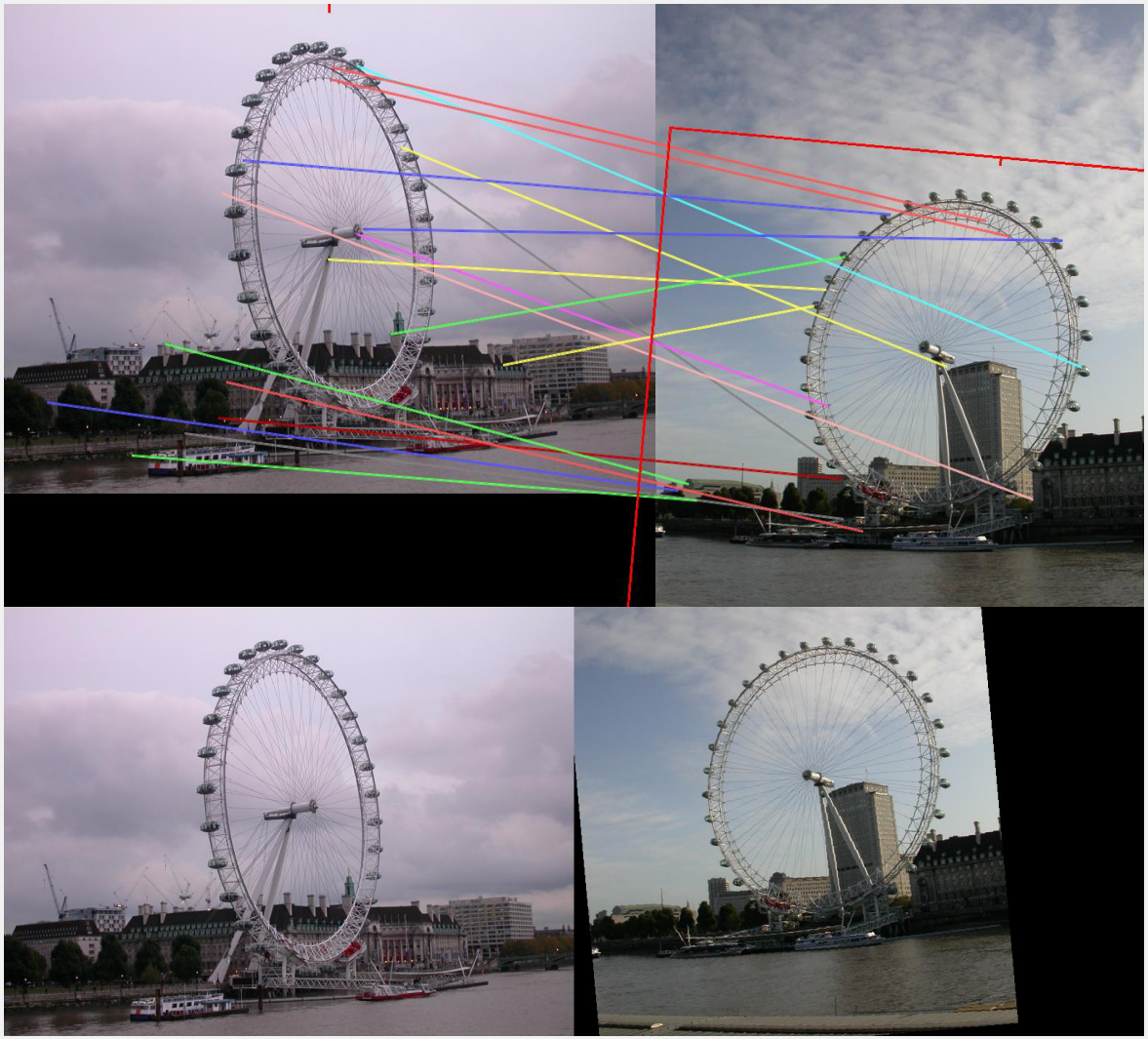
Similarity Between Corresponding Regions

Based on Image Distortion Model
- Ignore pixels outside query regions

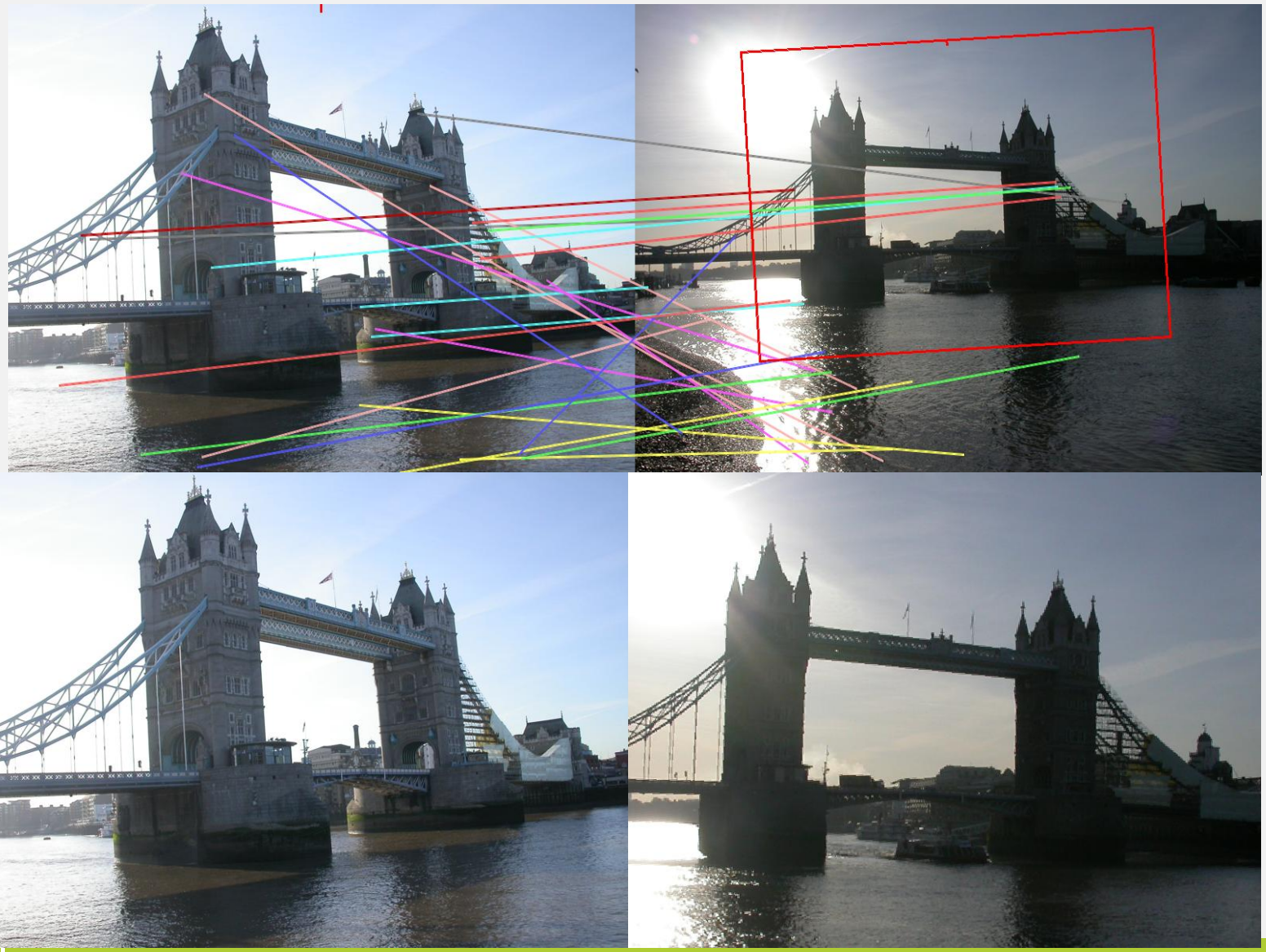
Relevance Feedback

Whenever useful to adapt to user

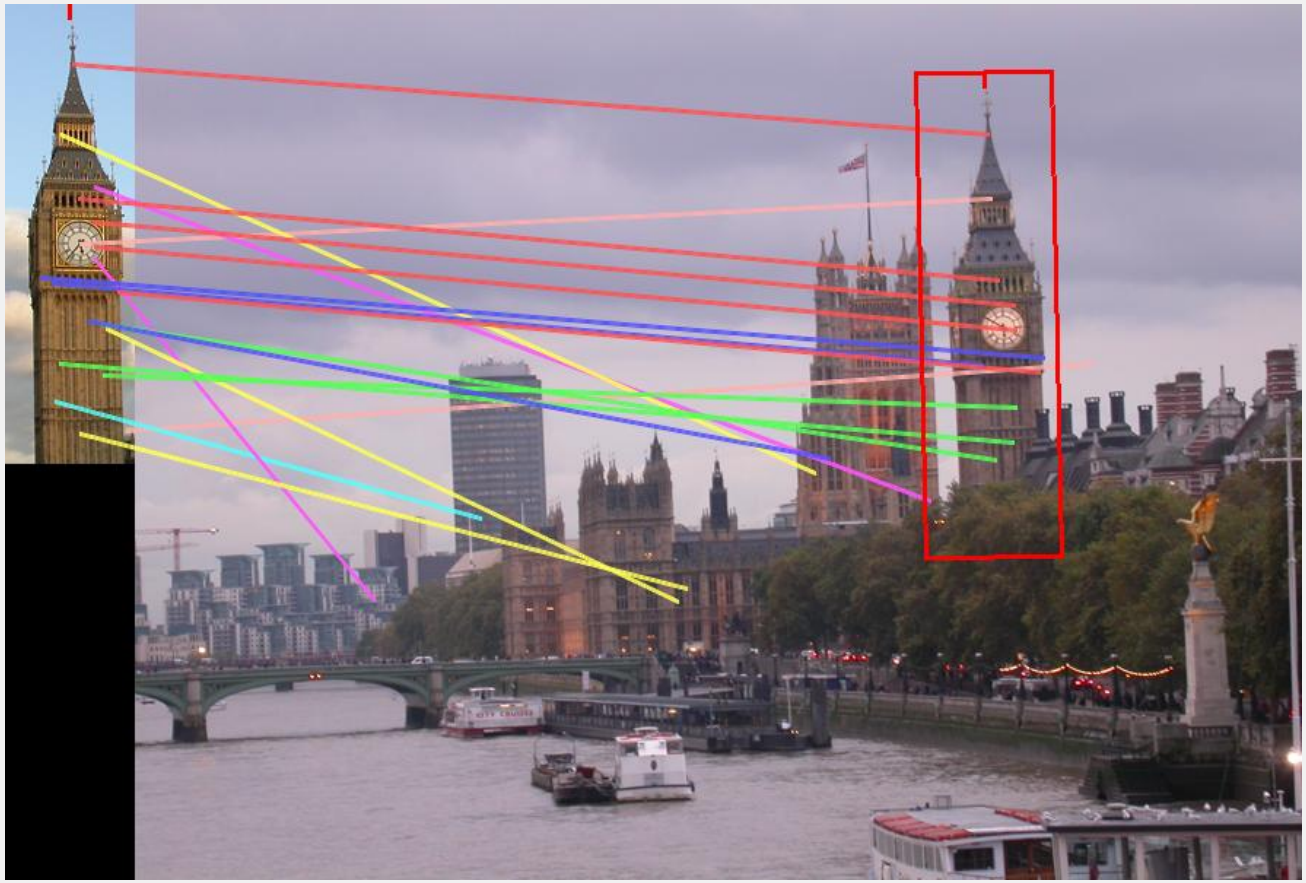
Examples – London Eye



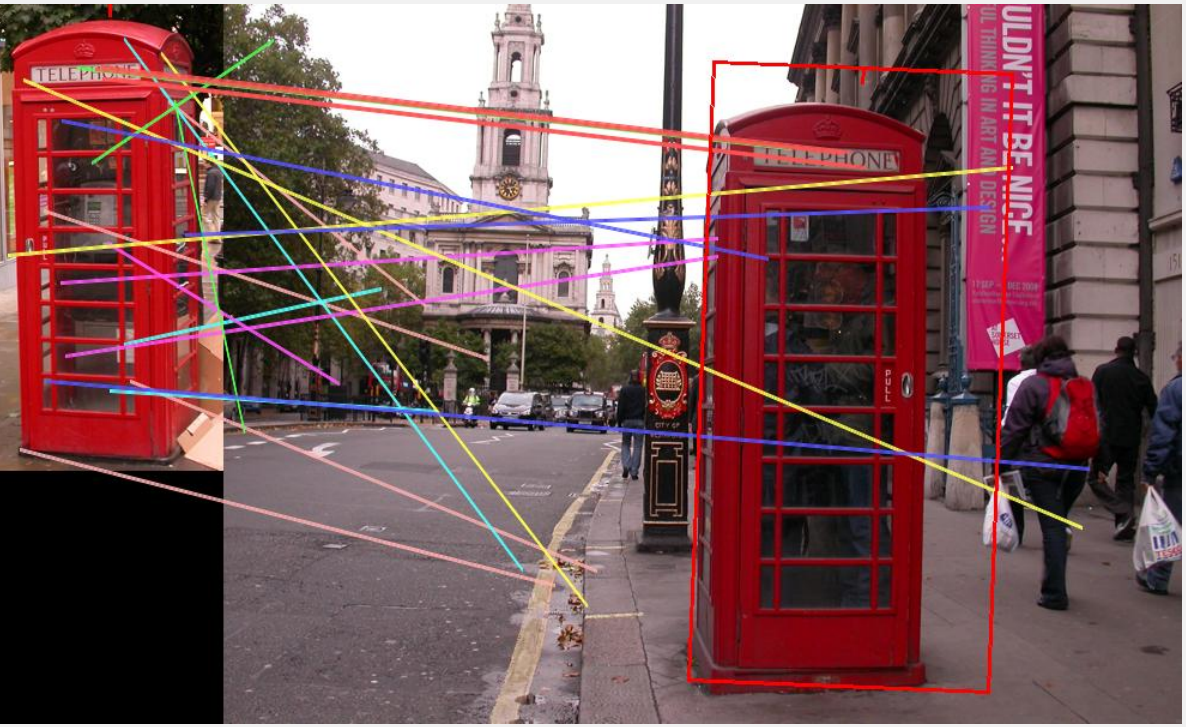
Examples – Tower Bridge



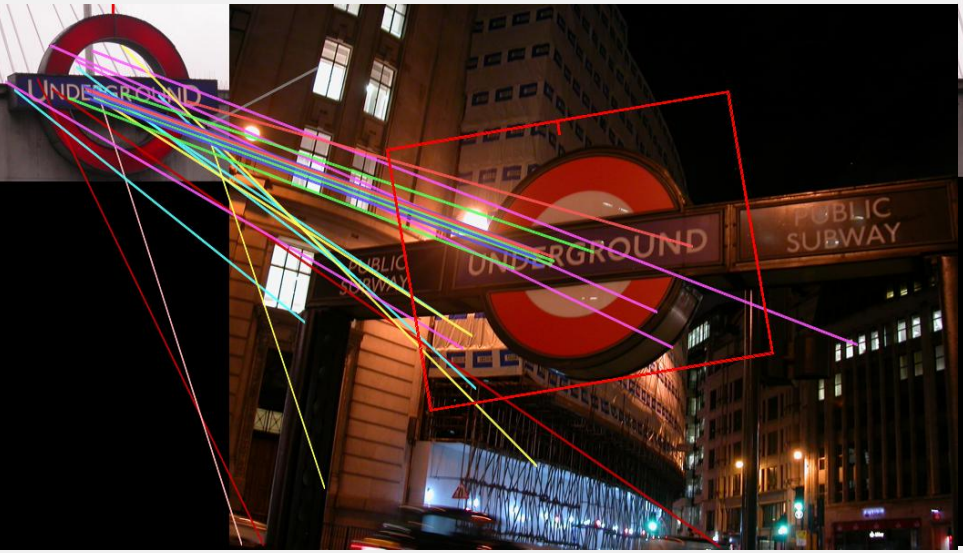
Examples – Big Ben



Examples – Phone Booth



Examples – Underground



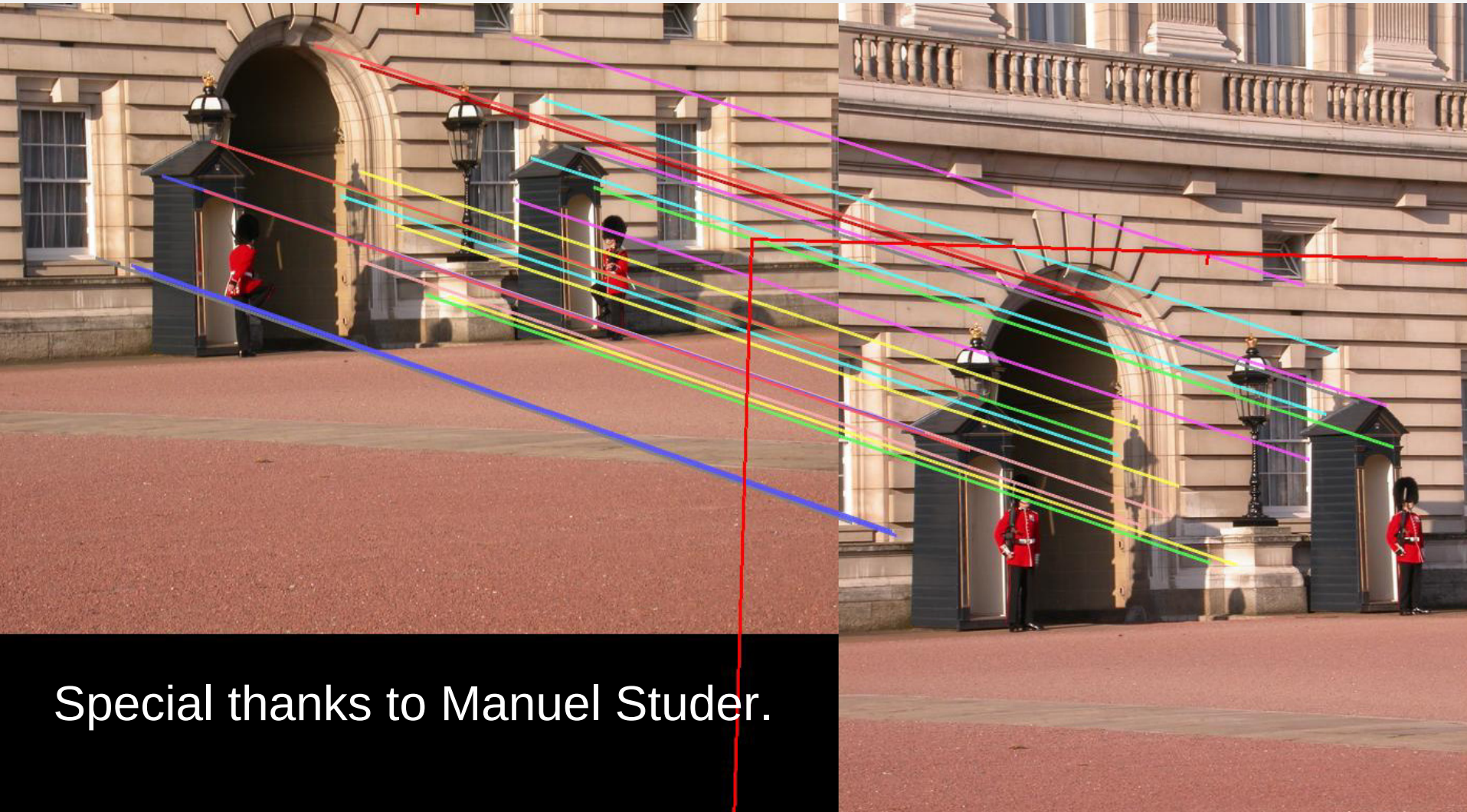
Examples – Underground (2)

Outlook

- Work on Keypoints
  - SIFT is ideal for all images
  - Use additional color information in color images
  - Edge-based keypoint descriptors required for sketches
- Combinations of regions
  - Semantics and implementation of AND, OR, AVERAGE
- Evaluate approach
- Distributed computation to reduce execution time

Thanks!

Thank you for your attention.



Special thanks to Manuel Studer.